

Restoration success of British floodplain meadows

By E ROTHERO and I TATARENKO

The Open University, Walton Hall, Milton Keynes, Buckinghamshire MK7 6AA, UK
Corresponding Author Email: emma.rothero@open.ac.uk

Summary

The Floodplain Meadows Partnership started a national survey (England and Wales) of floodplain-meadow restoration in 2016 by visiting 52 restoration fields. These fields encompassed a wide range of restoration methods and histories, with different degrees of success when evaluated against MG4 grassland as the main target plant community. Of the 52 fields visited, 21 were considered to be progressing well, whilst the remaining 31 had at least one issue that obstructed successful restoration. These issues can be broadly classified as: suboptimal management (39%), excessive nutrient availability (26%), excessive waterlogging (19%) and use of suboptimal propagules (16%). Maintenance of the soil-nutrient balance within the range recommended for the MG4 community should greatly improve the success rate of restoration projects. If nutrient levels on the site are excessive, an early hay cut in June, or double hay cut, should be considered as the most efficient methods for bringing the nutrient balance to the target for the plant community. The survey showed that different species vary greatly in their rate of establishment. Vegetation of MG6, MG7 and MG9 grasslands, according to the National Vegetation Classification, was most widely represented on the restoration sites. MG4 and MG8 plant communities were each recorded in less than 3% of fields.

Key words: Floodplain meadows, restoration methods, flood, soil nutrients, herbaceous plant communities

Introduction

Floodplain meadows are semi-natural ecosystems, some of which have been managed for hay and animal grazing for a thousand years (McGinlay *et al.*, 2016). Consistent traditional management supports an assemblage of species-rich plant communities through long-term spatial and temporal niche segregation (Silvertown *et al.*, 1999). MG4 *Alopecurus pratensis-Sanguisorba officinalis* grassland (Rodwell, 1992), which in common with other types of species-rich meadow is thought to have declined in extent by 98% over the past century, has become a major target in recent years for restoration on British floodplains (Lawson & Rothero, 2016).

This paper presents an analysis of a national survey (England and Wales) of floodplain-meadow restoration projects. Surviving MG4 stands have been taken as reference sites against which to evaluate restoration success. In many cases they have also served as ‘donor sites’ providing seeds or green hay for subsequent propagule introduction on restoration sites. Nationwide, these restoration sites encompassed a wide range of restoration histories, with very different levels of success. They are located on floodplains of various sizes and experience a wide variety of hydrological regimes, flood frequencies and soil fertility levels.

The survey was started in 2016 on 52 restoration fields. A variety of restoration projects were assessed in this study, including four old sites restored in 1970s and 1990s, as well as a range of more recently restored fields. The initial condition of the fields ranged from arable to improved pasture, restored by application of commercial or brush harvested seed mixtures or green hay. The analysis of data from such diverse fields proved to be difficult and is not fully comprehensive. However, we believe it is reflective of more general trends in floodplain meadow restoration projects nationwide. Further data are to be collected in 2017 and 2018.

Materials and Methods

Information collected for each site covered two main components: 1) historic description of the site, restoration technique applied, and current site management, and 2) survey of the current vegetation and soil status in each field.

- 1) Land owners and site managers were interviewed as part of the survey process following a standard proforma, to glean information on current management, site history, restoration dates and methods used, hydrological regime, manager objectives and anything else the manager felt was relevant. The interviews took place either in advance on the telephone, or during the site visit at the same time as surveys were undertaken, depending on the availability of the site manager or landowner.
- 2) Botanical surveys on the restoration fields were carried out in May–June 2016. A standard survey method of estimation of plant species projective cover (%) on 1 m × 1 m plots was applied (Wallace, 2012). Five plots were surveyed on 42 out of the 52 fields visited, but not in each possible plant community. The aim was to have an overview of vegetation types developing on the meadow rather than to identify and describe possible NVC communities in detail. A CEH-developed software MAVIS (<https://www.ceh.ac.uk/services/modular-analysis-vegetation-information-system-mavis>) was used for calculation of the vegetation community in each field. The remaining ten fields were surveyed on a walk-through basis for a general estimate of the site condition; no MAVIS or Ellenberg calculations were performed for these fields. Soils in the fields were described after augering the soil profile using a 5 cm Dutch auger down to 120 cm depth, where feasible. Using cores from certain depths, soil texture, coloration and inclusions according to the standard techniques were identified (Avery, 1980). On most occasions, the presence of a gravel or sand layer indicated the end of the soil profile.

Data analysis

Species richness was estimated on each plot and averaged per field. Ellenberg indicator scores for soil wetness (F), reaction (R), and nutrient content (N) (Ellenberg, 1988) were also calculated by MAVIS for each plot, followed by averaging of the score per field.

Management and ownership data were used to classify sites according to whether they were managed by a community group, private landowner, private company or charity. Sites were also classified according to their current restoration status, as category 1 (start again), category 2 (making progress), category 3 (excellent outcome) or category 4 (not a restoration site).

Results

Ownership and management

The sites visited varied in the nature of ownership and management (Fig. 1); with private landowners being the most frequently visited. Of the 52 fields, seven were not in an agri-environment scheme and for a further seven we have not been able to establish their status, leaving the remainder (38) in some form of agri-environment scheme. Of the seven sites not in a scheme, three were under the management of the local Wildlife Trust, who were unable to apply for an agri-environment scheme grant due to ownership restrictions, but were able to receive funding through an alternative grant to cover management costs.

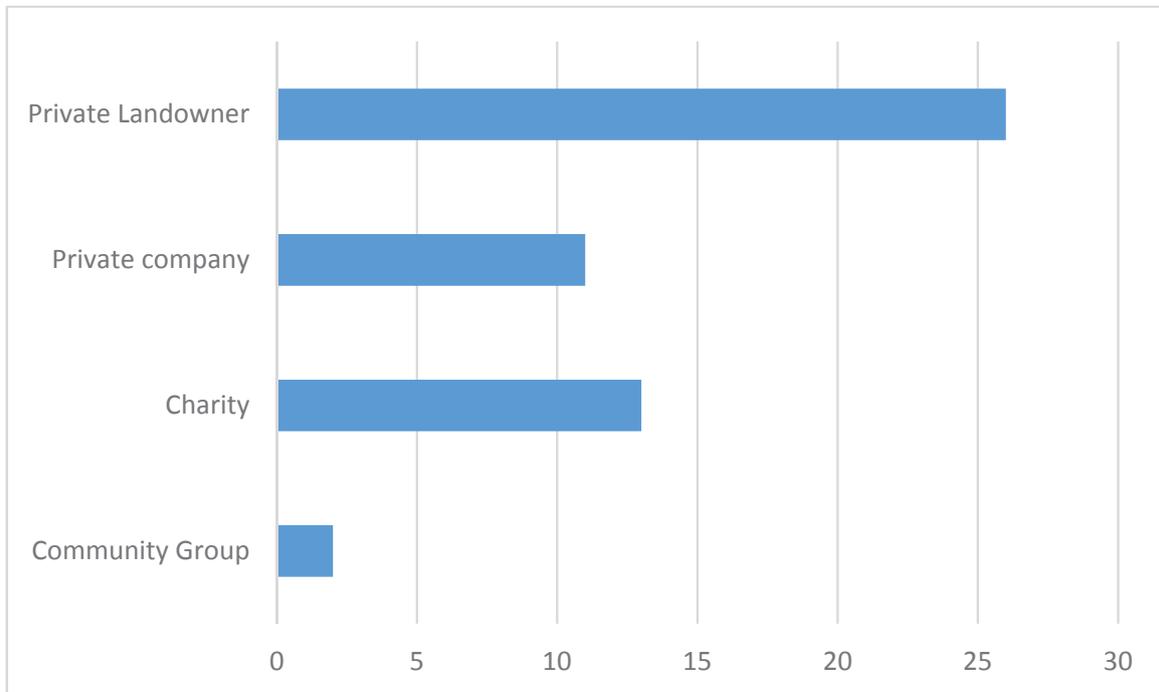


Fig. 1. Site management responsibilities for 52 restoration sites in England and Wales.

Ownership, and involvement in an agri-environment scheme tends to define the method of restoration carried out, and the type and consistency of management of the restored meadow after the restoration intervention. Private landowners were able to use a variety of restoration methods including hand-picked seed mixtures and plug plants. Private companies (commercial farming organisations) and charities tended to use commercial seed mixtures and green hay for seeding their sites. Post restoration management should involve an annual hay cut and aftermath grazing, however specific management requirements are typically defined by the scheme (e.g. in a Higher Level Stewardship scheme, the hay cut is often allowed only after 15 July). This can make the restoration process on nutrient-rich sites very problematic, as an early cut (June) is the most desirable way of reducing soil nutrient levels.

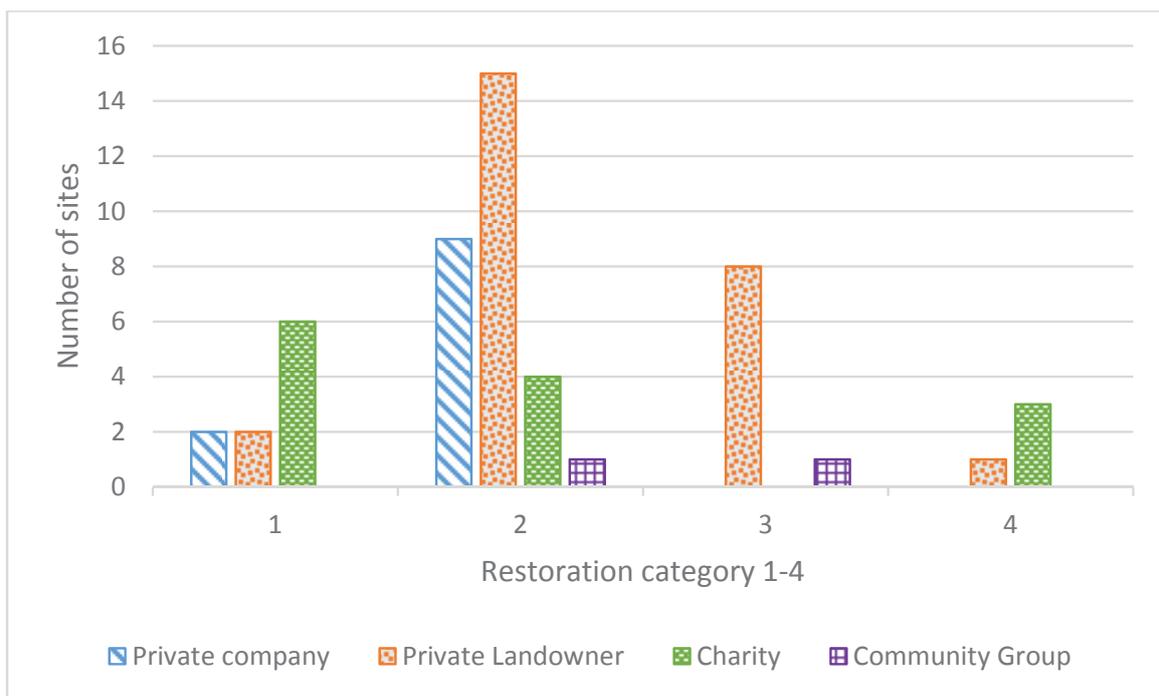


Fig. 2. Management responsibility for numbers of sites with category of restoration progress. Categories along x axis as follows: 1 - start again, 2 - making progress, 3 - excellent outcome or 4 - not a restoration site.

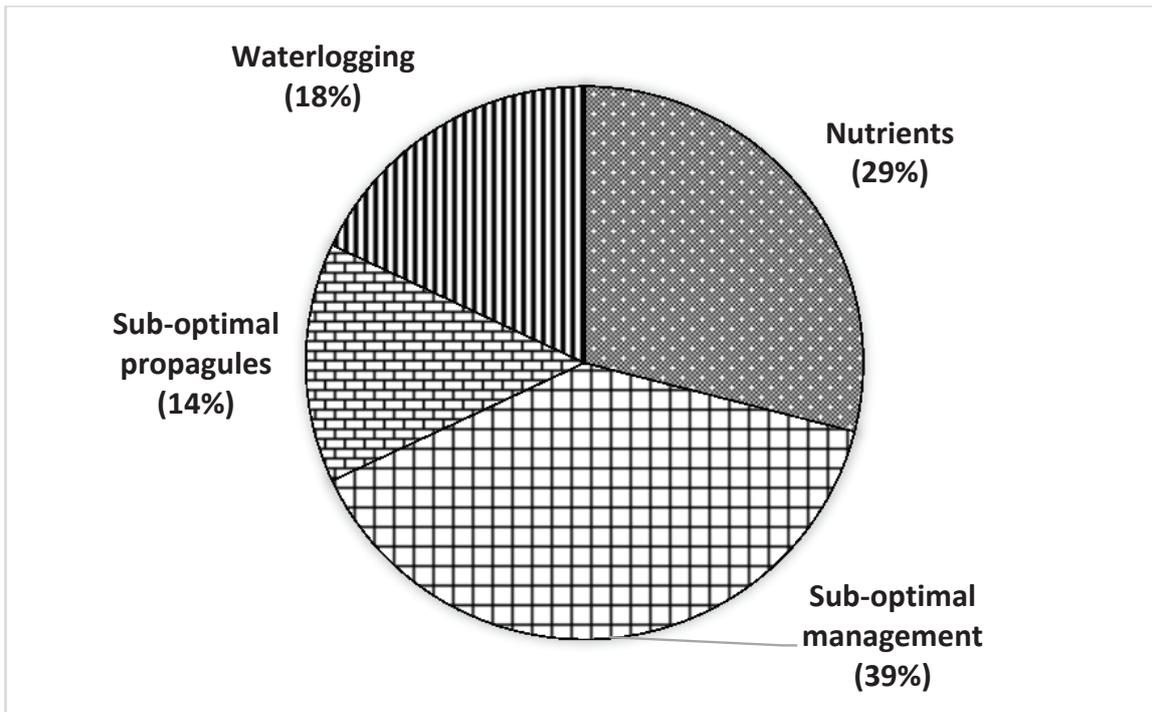


Fig. 3. Reasons for failing to move towards a target community for 28 floodplain meadow restoration sites in England and Wales (those classed as needing to start again, or making progress, but not including those classed as excellent or not restoration).

Of the 52 fields, four were not actually restoration sites (category 4) and nine were considered to be category 3 (excellent outcome). The rest (39) fell into either category 1 (start again) or category 2 (making progress) (Fig. 2).

Another common obstacle to restoration success is the failure of the hay cut because of weather and untimely flooding. On some sites aftermath grazing wasn't possible because of a lack of grazing animals. In total, sub-optimal management is responsible for 39% of failures in restoration success (Fig. 3).

Vegetation

In general, vegetation on the restored sites can be classified into 17 plant communities (Table 1), according to the National Vegetation Classification (Rodwell, 1992). The communities mainly belong to the category of 'Mesotrophic Grasslands' (MG), with a few exceptions. The Perennial Rye-grass community (MG7) is represented by all six sub-communities (79 quadrats). MG9 (*Holcus lanatus-Deschampsia cespitosa* grassland) was represented in 26 quadrats and MG6 (*Lolium perenne - Cynosurus cristatus* grassland) in 24. MG10 (*H. lanatus-Juncus effusus* rush-pasture) and MG5 (*C. cristatus - Centaurea nigra* grassland) communities were three times more frequent on the restoration fields than MG3, MG11, MG4 (*Alopecurus pratensis - Sanguisorba officinalis* grassland) and MG8 (*C. cristatus - Caltha palustris* grassland) communities.

Similarity coefficients, showing how close the vegetation on a particular field matches the various NVC-types, were calculated in MAVIS. Most scores calculated from the constancy tables were in the range of 40–60%. MAVIS scores exceeded a similarity coefficient of 60% in only 6% of the sites. These were mainly observed in the more mature plant communities, for example Church Farm (restoration started in 1978), although a similarity score over 60% was also calculated for a one year old restoration field: Somerford Mead East (Oxfordshire), classified as MG4, which probably reflects a good germination rate of species from the donor site and good soil conditions in the receptor site.

Table 1. Number of quadrats recorded (from a total of 389) against different NVC communities

NVC community code	Community Name	No. quadrats
M22	<i>Juncus subnodulosus</i> - <i>Cirsium palustre</i> fen meadow	3
M27	<i>Filipendula ulmaria</i> - <i>Angelica sylvestris</i> mire	2
MG1	<i>Arrhenatherum elatius</i> grassland	6
MG3	<i>Anthoxanthum odoratum</i> - <i>Geranium sylvaticum</i> grassland	20
MG4	<i>Alopecurus pratensis</i> - <i>Sanguisorba officinalis</i> grassland	15
MG5	<i>Cynosurus cristatus</i> - <i>Centaurea nigra</i> grassland	46
MG6	<i>Lolium perenne</i> - <i>Cynosurus cristatus</i> grassland	72
MG7	<i>Lolium perenne</i> leys	79
MG8	<i>Cynosurus cristatus</i> - <i>Caltha palustris</i> meadow	12
MG9	<i>Holcus lanatus</i> - <i>Deschampsia cespitosa</i> grassland	68
MG10	<i>Holcus lanatus</i> - <i>Juncus effusus</i> rush pasture	49
MG11	<i>Festuca rubra</i> - <i>Agrostis stolonifera</i> - <i>Potentilla anserina</i> grassland	10
MG12	<i>Festuca arundinacea</i> grassland	1
MG13	<i>Agrostis stolonifera</i> - <i>Alopecurus geniculatus</i> grassland	1
OV21	<i>Poa annua</i> - <i>Plantago major</i> community	1
OV26	<i>Epilobium hirsutum</i> community	1
SD17	<i>Phleum arenarium</i> - <i>Arenaria serpyllifolia</i> dune annual community	3

The dominance of communities associated with well drained soils, such as MG7, MG6, and MG5 is in good agreement with the Ellenberg indicator values of soil wetness, being in the range of 5–6 in the majority of fields (Fig. 4). On the other hand, two widespread communities usually found on poorly drained permanent pastures, MG9 and MG10, are linked with Ellenberg values of 6.5–7. Inundation communities such as MG11, MG12, and MG13 were very infrequent in the fields surveyed in 2016.

Effectiveness of different restoration methods

Five different types of restoration were used on the sites surveyed in 2016 (Fig. 5). There was no relationship observed between the condition of the site prior to restoration, and the restoration technique chosen. Commercial seed mixtures (CSM) as well as dry hay (DH) were predominantly used in earlier restoration projects (1970–1990s). CSM were still in use after 2010 but it is the green hay (GH) technique that was used most widely after then. Wild seed mixtures (WSM), often locally hand-picked, were only used by the most enthusiastic managers/owners, along with plug plants.

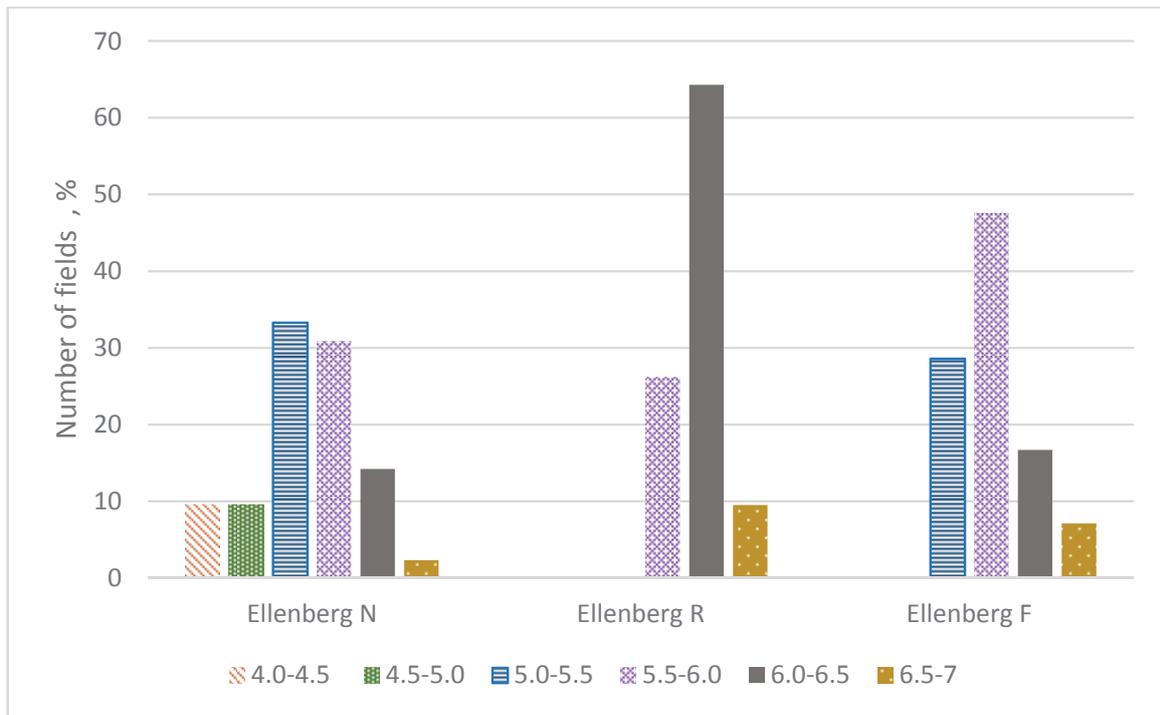


Fig. 4. Distribution of Ellenberg scores measured on 42 restoration fields.

A 'passive restoration' method, i.e. solely changing management of the field from pasture to hay without any further addition of hay or seeds, happened at 6% of sites. An example is Gunby Hall, Lincolnshire where management was changed following a visit by a local meadow restoration advisor in 1996 from sporadic hay cuts and occasional fertilisation to an annual hay cut and regular grazing for restoration purposes. Very good progress can be seen 20 years later. Recent sites where passive management has occurred have shown very little sign of progress yet. This 'changing management' restoration technique without other intervention requires a long-term approach (possibly decades), consistency and patience, before the site can be seen as a restoration success.

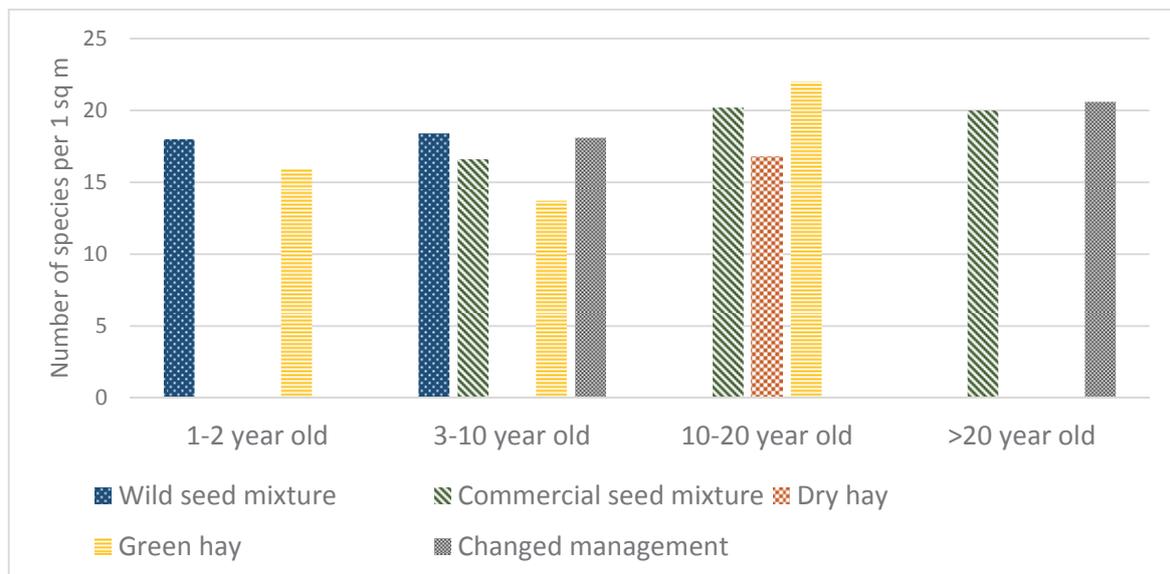


Fig. 5. Species richness on sites of different ages and different restoration techniques.

Species richness is one of the main criteria for determining restoration success (Lawson & Rothero, 2016). Measured by species richness, the effectiveness of dry hay spread on sites of similar restoration age was lower than of green hay (Fig. 5). However the green hay technique appeared

to be less effective on 3–10 year-old fields, compared to the wild seed mixture and ‘changing management’ methods. Species richness on most fields 10–20 years old, was higher than on more recent restoration sites regardless of restoration technique applied.

Effects of environmental factors on restoration success

A) Flood effect

Restoration projects on floodplains can be affected by natural events such as untimely floods. Of the 52 fields visited in 2016, five were flooded soon after green hay application, or during the first years after restoration intervention. Four of these were adjacent and treated in the same way. Floods happening soon after hay application can have a negative effect on species establishment because many propagules may be carried away in flood waters.

B) Excessive nutrients

Soil fertility (Ellenberg N) varied widely on the surveyed fields ranging from 4–7 (Fig. 4). Some variability in soil nutrient content was also observed within several restoration sites. Floods drop sediments on the fields, enriching the soil with nutrients. The majority of the sites surveyed in 2016 were flooded irregularly or briefly, and soil fertility remained relatively low: Ellenberg N 4.5–5.5 (Fig. 4). On a few fields, prolonged and regular floods have resulted in higher nutrients. High levels of soil nutrients on some fields were associated with historical improvement of the fields prior to restoration. Of the 28 sites in categories 1 and 2, excessive nutrients in the soil were responsible for 29% of the failure in restoration processes (Fig. 3). There is a negative correlation ($R^2=0.43$) between Ellenberg N values and the number of species per square metre (regression $P<0.001$).

Discussion

Restoration of floodplain meadow vegetation on British floodplains encompassed a wide range of restoration techniques, local site conditions and management procedures which can all affect restoration success. The different restoration methods were all shown to be successful if the hydrological and hydro-chemical regime on the floodplain was suitable for restoration of the particular target community. Environmental variables should be assessed and modelled at the time of planning any restoration project, to ensure a realistic target plant community is expected as an outcome (Duranel *et al.*, 2007).

Management after restoration is a key tool to bring the site closer to the target vegetation type. Most of the restoration sites surveyed in 2016 were grazed soon after propagules were applied to the field. Grazing is a powerful management tool, which on its own can ensure a high level of restoration success (Gilhaus *et al.*, 2014). Thoughtful and sensible management of grazing animals brought an improved pasture up to the standard of species-rich MG8 community at the Burgate Cross field in Hampshire, and at Wardle’s Farm in Lincolnshire. However, overgrazing of newly sown fields can slow down the establishment of species-rich vegetation, as was observed on Long Meadow (Oxfordshire). Aftermath grazing was shown to be a key element promoting recreation of species-rich meadows (Woodcock *et al.*, 2011), however, it appears to be absent on many restoration fields because of a lack of grazing animals. Under such circumstances, the hay cut becomes even more important. In the absence of aftermath grazing, a second cut is highly recommended in the autumn. This not only helps with the removal of excessive nutrients and unwanted species on the meadow (Newman, 2012), but also prevents litter from building up and blocking the growth of young seedlings (Kurkin, 1984).

Reflecting the variability in micro-topography and ecohydrology on floodplains, plants assemble themselves in a range of plant communities (Wheeler *et al.*, 2004; Carrington, 2010). Communities occurring on floodplains are mainly referred to as mesotrophic grasslands (MG) with 13 types described in the National Vegetation Classification (Rodwell, 1992) and amendments (Wallace &

Prosser, 2016). In areas of depressions, ponds and ditches with waterlogged soil, swamp communities (S) may also be present. The range of these mesotrophic grassland communities have been recorded and mapped on key floodplain meadow reference sites such as North Meadow National Nature Reserve (Wiltshire) and the Oxford Meads (Oxfordshire) (Wallace *et al.*, 2008). From the survey of restoration fields in 2016, several plant communities were the top scoring NVC types based on five botanical quadrats spread across the meadow. One of the survey objectives was to represent the current vegetation of the entire meadow, therefore we did not aim to locate all five quadrats within the borders of one chosen community. As a result, the top scoring NVC communities from the MAVIS programme are typically close to 50% and to each other. To a large extent they outline the vegetation diversity of the meadow. Their close scores also reflect the transitional status of the vegetation, developing from random species germinated on the restored site to a community organised according to hydrological niches.

Restoration success is affected by a variety of environmental factors. High residual fertility in grasslands targeted for restoration was shown to be a large obstacle for the establishment of diverse plant communities (e.g. Pywell *et al.*, 2003). Depending on distance to the river and the duration of flooding, sediment deposition could bring soil nutrients to a level incompatible with the restoration target community (Klaus *et al.*, 2011). Almost a third of restoration sites surveyed in 2016 showed some issues related to excessive soil nutrient content. Early hay cuts (Wotherspoon, 2015) as well as double cuts (Newman, 2012) have been shown to be the most effective measures for removal of excessive nutrients. Removal of the topsoil before applying seed mixtures or green hay, has been found to be a successful approach not only on several of the sites surveyed in the current project, but also on restoration sites in Central Europe (Holzel & Otto, 2003).

Conclusion

The majority of meadow restoration projects on floodplains in the UK assessed in 2016 were found to be moving towards a successful outcome. The time taken for restoration success can be long and affected by the lack of, or irregularity of, management, frequency of floods, and of excessive nutrients in the soil. Restoration of the main target community (MG4) was achieved in a few sites. Overall restoration success appears to be more a function of time and consistent management; restoration techniques appeared to be less important in determining a successful outcome.

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